Fakultät Elektrotechnik und Informationstechnik

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Predictive Resilience Curves and Rerouting for Threshold-Safe Quantum Networking

Project topic for Oberseminar Informationstechnik 2025/2026

Description:

Develop theory and methods to predict dips in a quantum network's resilience curve — that is, performance as a function of stress or fault level — and trigger reactive or proactive rerouting so that performance remains above a specified robustness threshold.

Students will formalize resilience-curve dynamics under noise and failure processes, design sequential dip detectors based on derivative or curvature signals and change-point tests with false-alarm guarantees, build short-horizon predictors with error bounds, and connect predictions to routing and control policies with provable safety-style guarantees.

Tasks:

1. **Formal Model and Threshold Safety**: Define a resilience curve as a function of a stress index such as loss, failure rate, or attack fraction; State the robustness requirement - at every time step, the resilience should be at or above a chosen threshold; Specify what is observable: noisy measurements of the resilience over time; List and justify assumptions such as smoothness or Lipschitz-like behavior of the curve, bounded noise, or simple mixing properties for the stress process.
2. **Dip Detection as Sequential Testing**: Design derivative and curvature-based detectors using finite differences; provide concentration-style guarantees for their estimates under noises; Formulate change-point tests such as CUSUM, Page–Hinkley, or sequential probability ratio testing; derive thresholds for false-alarm and missed-detection rates and the expected detection delay.
3. **Short-Horizon Prediction with Guarantees**: Choose a predictor class: linear–Gaussian state-space, Gaussian process with mild smoothness, or an online convex forecaster; Provide bounds on the prediction error over a short horizon phrased as confidence and define a safe prediction radius that ensures the future resilience will be above the threshold with high probability; clearly state all conditions under which the guarantees hold.
4. **Routing and Control as Safe Switching**: Model routing actions, such as selecting paths or mixing flows, that change the resilience curve. Design policies such as: (a) a threshold rule that switches to a safer action when predicted violation risk exceeds a chosen level, (b) a model predictive control policy with chance constraints, and (c) a learning-based switching policy over a finite set of actions with safety filters.

Keywords: Quantum Networks, Predictions, Entanglement Fidelity, Resilience Curve

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